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(54) Method for adaptively estimating reception quality

(57) The present invention relates generally to the field of estimating reception quality and particularly to a method of adaptively estimating reception quality for a signal transmitted over a transmission channel.

In radio communications systems, e. g. digital cellular radio systems according to the Global System for Mobile communications (GSM), an estimation of the reception quality for a signal transmitted over the radio channel is used for many purposes. As the transmission conditions on the transmission channel my vary strongly due to their statistical nature, the known methods for estimating the reception quality often do not provide a satisfactory estimate.

The present invention provides an estimate for reception quality of a signal transmitted over a transmission channel which is adapted to the transmission channel used for transmission of the signal. It is thus possible to provide an estimate which is optimised with regard to the transmission conditions.

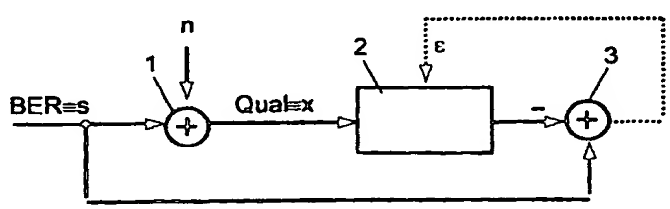

Fig. 1

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Description

TECHNICAL FIELD

[0001] The present invention relates generally to the field of estimating reception quality and particularly to a method of adaptively estimating the reception quality for a signal transmitted over a transmission channel.

BACKGROUND OF THE INVENTION

[0002] In radio communications systems, e. g. digital cellular radio systems according to the Global System for Mobile communications (GSM), an estimation of the reception quality for a signal transmitted over the radio channel is used for many purposes. One example is the use of the reception quality in algorithms which are provided for deciding on handovers as described e. g. in „The GSM System for Mobile Communications" by M. Mouly and M.B. Pautet, Palaiseau, 1992. The reception quality estimation (Qual) is based on the Bit Error Rate (BER) estimates derived in the system by Mobile Stations (MS) and Base Transceiver Stations (BTS) as a part of channel equalisation or decoding process. Usually Qual is reported within a reporting period of 480 ms via the Slow Associated Control CHannel (SACCH) by the MS. As the Qual value is available only every 480 ms, and as due to the nature of the transmission channel, which is influenced by a significant level of noise, i. e. statistical variations, fading, interference etc., the Qual values need to be averaged during the reporting period.

[0003] As the transmission conditions on the transmission channel my vary strongly due to their statistical nature, for many cases, e. g. more advanced techniques like voice transmission with an adaptive data rate, known as Adaptive Multi Rate (AMR), or packet data transmission having an adaptive data rate, known as General Packet Radio Service (GPRS), the simple averaging over a fixed period of time of the Qual values is not sufficient in order to provide a satisfactory estimate for the reception quality.

SUMMARY OF THE INVENTION

[0004] Accordingly, it is an object of the present invention to provide a method of adaptively estimating reception quality and particularly a method of adaptively estimating the reception quality for a signal transmitted over a transmission channel. It is the aim of the inventive method under consideration to avoid the drawbacks known from the state of the art.

[0005] The object is achieved by providing a method of adaptively estimating reception quality for a signal transmitted over a transmission channel, having steps of

estimating said reception quality,
determining an actual bit error rate by using a known bit sequence,
determining an error value for an estimation error of said estimated reception quality by comparing said estimated reception quality to said actual bit error rate,
adjusting an adaptive filter means in accordance with said determined error value,
and filtering said estimated reception quality with said adjusted adaptive filter means.

[0006] It is an advantage of the present invention, that it allows to provide an estimate for reception quality of a signal transmitted over a transmission channel which is adapted to the transmission channel used for transmission of the signal. It is thus possible to provide an enhanced bit error rate estimate which is optimised with regard to the transmission conditions.

[0007] The present invention will become more fully understood from the detailed description given hereinafter and further scope of applicability of the present invention will become apparent. However, it should be understood that the detailed description is given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The following detailed description is accompanied by drawings of which

Fig. 1 is a representation of adaptively estimating reception quality in principal according to this invention, and
Fig. 2 is a flow chart of a method of adaptively estimating reception quality according to this invention.

DETAILED DESCRIPTION

[0009] Following the invention will be explained for a GSM system. To those skilled in the art it is obvious that the present invention also is applicable to other wireless systems.

[0010] Depicted in Fig. 1 is a representation of adaptively estimating reception quality in principal. An actual bit error rate BER is modelled as a stochastic process and abbreviated with s. An estimated reception quality Qual consists of the bit error rate s disturbed by a noise sequence n representing the estimation error. In Fig. 1 an adder 1 adds the noise signal n to the actual bit error rate s forming the estimated reception quality signal x. The signal x is coupled to an adaptive filter 2 which is used to filter signal x according to the actual bit error rate s. To adjust the adaptive filter 2 the output signal of the adaptive filter 2 is coupled to an adder 3 and is subtracted form the actual bit error rate s. The output signal ε of the adder 3, which represents the error of the estimated reception quality signal x compared to the actual bit error rate s is used to adjust the adaptive filter 2 in order to minimise the mean squared error of the estimate, by using the error signal which is available at the output of filter 2.

[0011] The adaptive filter 2 can be formed by a linear Finite Response Filter (FIR) defined by a set of coefficients

$$w[k],\ k \in [L,K] \tag{1}$$

[0012] With the abbreviations as defined above for the actual bit error rate BER and the estimated reception quality Qual it is

$$\mathrm{BER} = s, \text{ and} \tag{2a}$$

$$\mathrm{Qual} = x \tag{2b}$$

[0013] As will be explained below, the value of the estimated reception quality x is equivalent to the actual bit error rate s plus an error n

$$x[m] = s[m] + n[m] \tag{3}$$

with m being a discrete time variable. The impulse response of the linear filter 2, as defined in equation (1) by its coefficients, is then chosen in order to minimise the resulting error ε according to the least mean square method, i.e.

$$\text{Minimise } \varepsilon^2 \text{ with subject to } w[k] \tag{4}$$

where

$$\varepsilon^2 = \sum_{m \in I} \left(s[m] - \hat{x}[m]\right)^2 \tag{5}$$

and

$$\hat{x}[m] = \sum_{k=L}^{K} w[k] \cdot x[m-k] \tag{6}$$

with I being a group of samples for which the mean value is built. K and L may be chosen in a way to get a causal or a non causal solution of equation (6). The system of linear equations resulting from equations (1) to (6) is

$$r_{SX}[k] = \sum_{j=K}^{L} w[j] R_{XX}[k-j], \quad k \in [K,L] \tag{7}$$

where $r_{sx}[k]$ and $R_{xx}[k\text{-}j]$ represent the cross and autocorrelation functions of s and x. This system of linear equations can be solved e.g. by direct matrix inversion, or by using a known algorithm like least mean square algorithm (LMS) or

recursive least squares algorithm (RLS).

[0014] The solution for the vector of coefficients **w** is using the direct matrix inversion method is:

$$\mathbf{w} = \mathbf{R}_{xx}^{-1} \cdot \mathbf{r}_{sx} \tag{8}$$

with

$$\mathbf{R}_{xx}^{-1}$$

being the inverted auto-correlation matrix of x and $\mathbf{r}_{sx}$ being the cross-correlation vector of s and x.

[0015] By choosing different values for K and L the adaptive filter 2 can represent a causal or non causal form, by applying symmetry constraints with regard to the time origin the filter function can be symmetric or non symmetric in the time domain. It can have a variable filter length in order to improve the filter quality. In addition a weighting function multiplied with the filter coefficients can be used. For greater detail and a better understanding of adaptive filter theory „Adaptive Filter Theory", by Simon Haykin, Prentice Hall, 1986, is incorporated by reference.

[0016] Following a method of adaptively estimating reception quality will be explained with reference to Fig. 2 which is a flow chart of a method of adaptively estimating reception quality according to this invention and shows the principal realisation of the adaptive estimation scheme in a wireless communication system. Fig. 2 shows a data source 20 which generates a known bit sequence. The known sequence of data source 20 is transmitted over a transmission channel 21. As the sequence of data produced by data source 20 known it is available on both sides of the transmission channel 21. Therefore, two data source 20 on both sides of the transmission channel 21 are shown. After transmission the quality of the received signal Qual is estimated 22. At the same time the actual bit error rate BER is calculated 23 by utilising the fact that a known bit sequence is generated by data source 20. Both the estimated reception quality Qual and the actual bit error rate BER are pre-processed firstly by using operations 24 and 25 in order to align the dynamic range of the stochastic variables and remove non-linear effects. For this purpose operations 24 and 25 can be e. g. logarithmic operations. The linearised and aligned values of Qual and BER are used in a way as explained above for linear optimisation 26, e. g. least squares optimisation, to adjust a set of coefficients of a filter 28. By adjusting the filter coefficients according to the result of the linear optimisation 26 an adaptive filter 28 is formed which is used to adaptively filter the reception quality estimate Qual of the estimation step 22. In that way the quality of the estimated and filtered value as available at output 29 of the filter 28 is improved, as it is adjusted to the actual transmission conditions on the transmission channel 21 used for transmitting the signal. Actual transmission conditions can vary e. g. with regard to the speed of the MS. The system can adapt then the filtering function to be an averaging function with a lower averaging time compared e. g. to the averaging time used for non moving MS.

[0017] As explained above, for calculating the actual bit error rate BER, a known bit sequence is necessary. Therefore, for adaptively filtering the estimated reception quality Qual, data source 20 has to provide a known bit sequence either when the system is installed to adjust the adaptive filter 28 according to the transmission channel, or the data source 20 has to provide the known bit sequence continuously or regularly within certain periods of time. After the adaptation of filter 28 a constant filter function, i. e. a fixed set of filter coefficients, can be applied to filter the estimated Qual values of step 22. In this case the components encircled by dashed line 27 do not have to be operative.

[0018] In a GSM system e. g. the silence descriptor frames (SID frames) sent and provided at discontinuous transmission (DTX) can be used as reference signals to generate the BER values as they contain known data symbols.

Claims

1. A method of adaptively estimating reception quality for a signal transmitted over a transmission channel, having steps of

    - estimating said reception quality,
    - determining an actual bit error rate by using a known bit sequence,
    - determining an error value for an estimation error of said estimated reception quality by comparing said estimated reception quality to said actual bit error rate,
    - adjusting an adaptive filter means in accordance with said determined error value, and
    - filtering said estimated reception quality with said adjusted adaptive filter means.

2. A method according to claim 1,

characterised in, that

said estimated reception quality and said bit error rate are linearised.

3. A method according to claim 2,
characterised in, that

for said linearisation a logarithm of said estimated reception quality and said bit error rate is formed.

4. A method according to one of the claims 1 to 3,
characterised in, that said steps of determining said error value and adjusting said adaptive filter means in accordance with said determined error value, is effected by linear optimisation.

5. A method according to claim 4,
characterised in, that

said linear optimisation is achieved by least mean square optimisation.

6. A method according to one of the claims 1 to 5,
characterised in, that

said steps of determining said actual bit error rate and determining said error value and adjusting said adaptive filter means in accordance with said determined error value is effected only once.

7. A method according to one of the claims 1 to 5,
characterised in, that

said steps of determining said actual bit error rate and determining said error value and adjusting said adaptive filter means in accordance with said determined error value is effected on a regular basis.

8. A method according to one of the claims 1 to 7,
characterised in, that

said transmission channel is a radio channel.

9. A method according to claim 8,
characterised in, that

said radio channel is a transmission channel in a GSM system.

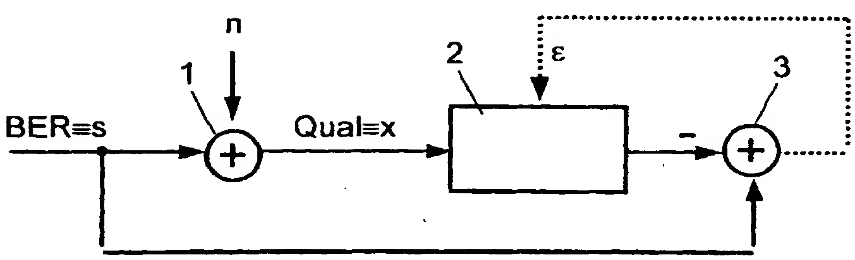

Fig. 1

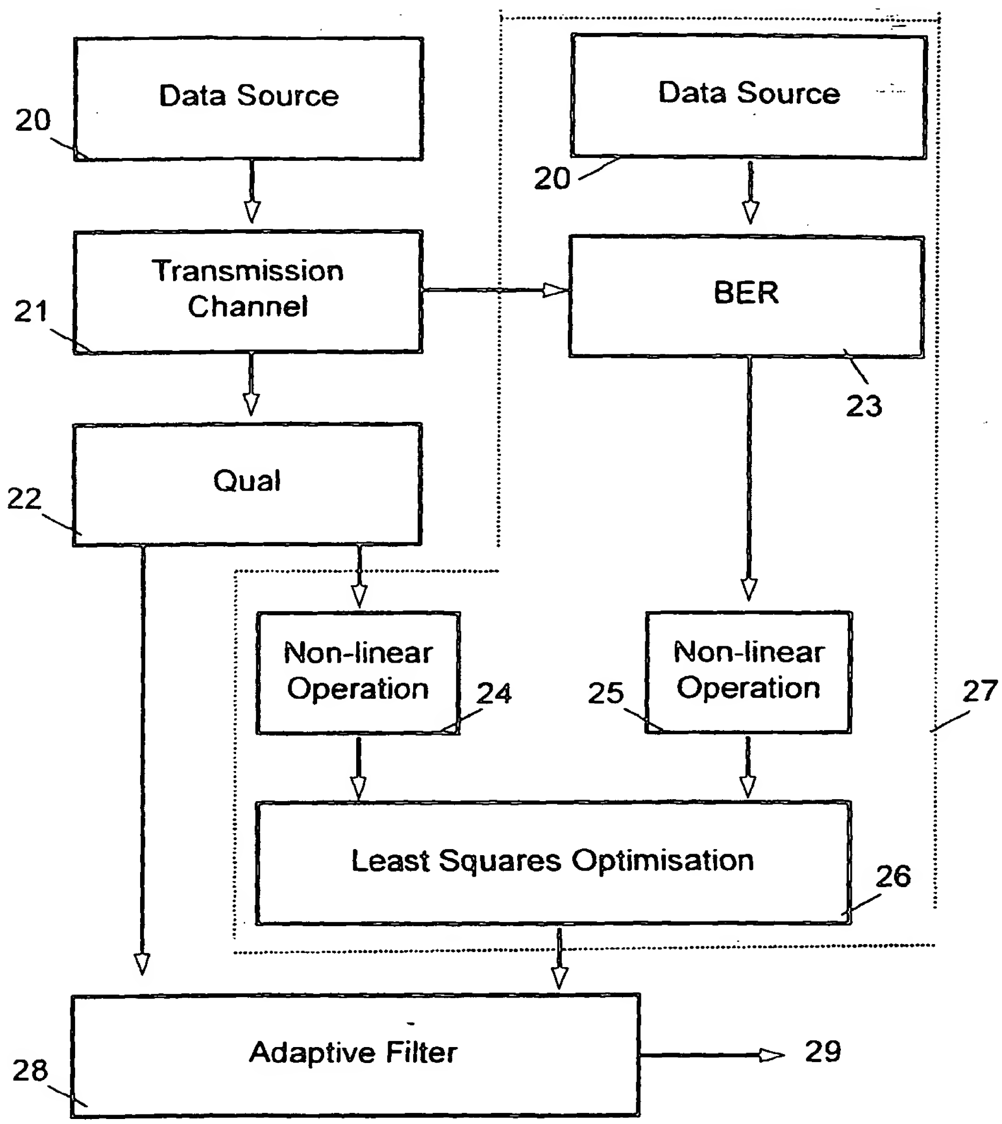
Data Source
20
Transmission Channel
21
Qual
22
Data Source
20
BER
23
Non-linear Operation
24
25
Non-linear Operation
27
Least Squares Optimisation
26
Adaptive Filter
28
29

Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 98 30 8339

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US 5 586 143 A (WHINNETT NICHOLAS W) 17 December 1996 * abstract; figures 1,3 * * column 1, line 21 - line 25 * * column 2, line 15 - line 41 * * column 3, line 10 - line 18 * * column 3, line 25 - line 37 * ---	1,4-6,8	H04L1/20
A	EP 0 722 226 A (NOKIA MOBILE PHONES LTD) 17 July 1996 * abstract; figure 3 * * column 2, line 6 - line 11 * * column 5, line 4 - line 33 * * column 6, line 20 - line 25 * * column 9, line 33 - line 42 * ---	1,4,7,8	
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	15 March 1999	Papantoniou, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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D : document cited in the application
L : document cited for other reasons

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EUROPEAN SEARCH REPORT

Application Number
EP 98 30 8339

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
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			TECHNICAL FIELDS SEARCHED (Int.Cl.6)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

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